ALIGNMENT METHOD AND APPARATUS FOR PIXILATED DETECTOR

DESCRIPTION

The present invention relates to the diagnostic imaging systems and methods. It finds particular application in conjunction with the nuclear imaging systems using solid state detectors (SSD) and will be described with particular reference thereto. It will be appreciated that the invention is also applicable to the other imaging systems using pixilated imaging devices, and the like.

Diagnostic nuclear imaging is used to study a radionuclide distribution in a subject. Typically, one or more radiopharmaceutical or radioisotopes are injected into a subject. The radiopharmaceutical is commonly injected into the subject's bloodstream for imaging the circulatory system or for imaging specific organs, which absorb the injected radiopharmaceutical. A radiation detector is placed adjacent to the surface of the subject to monitor and record emitted radiation. Often, the detector is rotated or indexed around the subject to monitor the emitted radiation from a plurality of directions. These projection data sets are reconstructed into a three-dimensional image representative of the radiopharmaceutical distribution within the subject.

Commonly, each detector head includes an array of photomultiplier tubes (PMTs) facing a single large scintillation crystal. Each radiation event generates a corresponding flash of light that is seen by the closest photomultiplier tubes. Each photomultiplier tube that sees an event puts out a corresponding analog pulse. The analog pulses from the individual PMT's are digitized and combined to generate x and y spatial coordinates of the location of scintillation event on the crystal face.

In recent years, however, a use of solid state detectors in nuclear cameras has proved to be beneficial. Solid state detectors include a large array of individual detectors each of which utilizes the photoelectric effect to detect radiation. More specifically, the received radiation photons liberate electrons from their orbits around atoms of the target material. The electrons are detected as an electrical signal.

Typically, solid state detector designs incorporate detector modules which each include a smaller array of individual detector elements, e.g. 256. The individual detector elements are few millimeters square. The detector modules, e.g. 50-60 in number, are installed in array on the motherboard, which is typically 20-40 centimeters on each side

to define the active surface of the detector. In these designs, the module has contact pins, with which each module plugs into the motherboard. The electrical contact pins are thin and fabricated of electrically conductive metal. The pins tend to flex and bend slightly during insertion into mating holes in the motherboard permitting each module to skew slightly. Misalignments among the modules produce inaccuracies in the individual detector element grid that cause corresponding inaccuracies in the resultant image. The installation of the modules into a whole array with high tolerances to form a precisely rectangular grid of individual detector elements is difficult.

Nuclear cameras, particularly SPECT cameras, have a collimator that restricts the directions from which radiation can approach and strike the detector. The collimators have a grid of thin walls which overlie gaps or interfaces between individual detector elements. Although the collimator grids can be manufactured with high tolerances, skewed or shifted detector modules cause misalignment between the collimator and the detector elements. Even small misalignments place the collimator walls over larger portions of the active faces of some detector elements than others. Variations in the degree, to which detector element active faces are shadowed by the collimator grid, alters the effective size of some detector elements relative to others changing the relative amount of radiation received and degrading the resultant image.

There is a need for an alignment technique that would reduce the costs and complexity of alignment. The present invention provides a new imaging apparatus and method which overcomes the above-referenced problems and others.

In accordance with one aspect of the present invention, a detector for a nuclear imaging system is disclosed. The detector comprises a plurality of sockets which each support an array of individual detector elements. Each socket includes a plurality of electrical connectors and a socket alignment structure. The sockets are received on a circuit board that includes a plurality of electrical connection means which electrically connect with the electrical connectors, and a circuit board alignment structure which mates with the socket alignment structure to align the sockets and the individual detector elements to the circuit board. A means is used for mounting a collimator to the circuit board in alignment with the circuit board.

In accordance with another aspect of the present invention, a method of assembling a detector for a nuclear imaging system is disclosed. A plurality of sockets, which each include an array of individual detector elements, a plurality of electrical connectors, and socket alignment structures, is inserted into a circuit board which includes a plurality of electrical connections which electrically connect with the electrical connectors as the sockets are inserted, and circuit board alignment structures, which mate with the socket alignment structures as the socket is mounted to align the arrays of detector elements with the circuit board and each other. A collimator mounting means is mounted and aligned to the circuit board such that the collimator mounting means is aligned with the arrays of detector elements.

One advantage of the present invention resides in improving performance of detector by precisely aligning individual receptive elements to the openings in collimator.

Another advantage of the present invention resides in using separate non conducting alignment structures thus reducing cost and complexity of alignment.

Still further advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of nuclear imaging system in accordance with the present invention;

FIGURE 2 is a diagrammatic illustration of a detector;

FIGURE 3 is a diagrammatic illustration of a portion of a substrate; and

FIGURE 4 is a diagrammatic illustration of a portion of a substrate and a frame.

With reference to FIGURE 1, a nuclear imaging device **10** typically includes a stationary gantry **12** that supports a rotating gantry **14**. One or more detector heads **16** are carried by the rotating gantry **14** to detect radiation events emanating from a region of interest or examination region **18**. Each detector head includes a two-dimensional array of detector elements or detector **20**. The detector arrays are preferably solid-state detectors, which convert gamma radiation directly into electrical charge. Each head **16** includes circuitry **22** for converting each radiation response into a digital signal indicative of its location (x, y) on the detector face and its energy (z). A collimator **24** controls the direction and angular spread, from which each detector element of the array **20** can receive radiation.

Typically, an object to be imaged is injected with one or more radiopharmaceutical or radioisotopes and placed in the examination region **18** supported by a couch **26**. The presence of the radiopharmaceuticals within the object produces emission radiation from the object. Radiation is detected by the detector heads **16** which are, preferably, angularly indexed or rotated around the examination region **18** to collect the emission data from a plurality of directions. The projection emission data (x, y, z) and an angular position (θ) of each detector head **16** around the examination region **18** are stored in a data storage **28**. A reconstruction processor **30** processes the event and detector orientation data from the data storage **28** into a volumetric image representation. The image representation is then stored at a volume image memory **32** for manipulation by a video processor **34** and display on an image display **36** such as a video monitor, printer, or the like.

With reference to FIGURE 2, the detector **20** includes a substrate or a circuit board **40**, on which detector modules **42** are mounted in a close packed tile arrangement. Each detector module **42** includes a socket **44** and a crystal array **46**. Each crystal array **46** is preferably divided into 256 individual detector elements or pixels **48**. The substrate **40** includes rectangular openings **50**. A plurality of holes or pin sockets **52** is disposed about the openings **50** to electrically connect with the detector modules **42**. More specifically, each module's socket **44** employs electrical connectors or pins **54** disposed about its perimeter. The electrical connector pins **54** are inserted into the plurality of mating pin sockets **52** to establish the electrical connections with the crystal **48** and the associated electrical components disposed on the substrate **40** or in the detector head **16**.

With continuing reference to FIGURE 2, the detector **20** further includes a frame **60** that is mounted to the substrate **40** to support the collimator **24**. The collimator **24** includes a lead grid **62** that is made from pieces that mate together to make a square matrix of apertures **64**, which spans the entire array of detector modules. As explained in greater detail below, the frame **60** positions the collimator **24** such that vanes **66** that define each square collimator aperture **64** are aligned with the gaps or interfaces **68** between individual detector elements **48** on the circuit board **40**.

With reference to FIGURE 3, each socket **44** includes contact portion **70** at which the crystal array **46** is electrically connected to the electrical contact pins **54**. Each socket further includes two or more alignment pins **72**, positioned diagonally from each other. Corresponding mating alignment openings or holes **74** are provided on the substrate **40**. The alignment pins **72** are preferably made of high strength steel, but other rigid, hard to deform materials are also contemplated. The placement and cross section of the alignment pins **72** and the alignment openings **74** are manufactured with high precision. The interaction of the alignment pins **72** and holes **74**, as the sockets **44** are inserted into the circuit board **40**, precisely aligns the detector modules **42** and the individual detector elements **48**. Of course, the alignment mechanism might be reversed, with the pins provided on the substrate and mating openings on the socket.

With reference again to FIGURE 2 and further reference to FIGURE 4, the frame **60** has a rectangular face **80** having a longer dimension **82** and a shorter dimension **84**. Four alignment openings are defined through the frame **60** and match with alignment openings **86** defined in the substrate **40**. More specifically, a pair of primary frame alignment openings **88** is defined in the shorter dimension **84**, and a pair of secondary frame alignment openings **90** is defined in the longer dimension **82**. Typically, only one pair of frame alignment openings is used to mount the frame **60** to the substrate **40**, to account for the effect of thermal dilatation. Preferably, the frame alignment openings **88** positioned along the shorter dimension **84** are used to mount the frame **60** to the substrate **40**, although both pairs are used in the alignment process. The system is constructed from different materials, each of which expands and contracts at different rates. Having the alignment structures positioned across the shorter dimension **84** reduces the effect of thermal stress. Of course, if the materials used in the system are changed to reduce thermal

stress, the secondary frame alignment openings **90** positioned about the longer dimension **82** might be used.

With continuing reference to FIGURES 2, 3 and 4, once the frame **60** is aligned with the circuit board **40**, it is also aligned with the detector modules **42** and the individual detector elements **48**. To align with the collimator **24**, the frame **60** has inside surfaces **92** around its central opening that mate with exterior surfaces **94** of the collimator **24**. Alternatively, the collimator **24** can have a flange with alignment and mounting pins **96** that are received in alignment and mounting apertures **98** in the frame. In this manner, the collimator apertures **64** are fixedly aligned with the individual detector elements **48** with a tolerance of +/-10 micron.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon a reading and understanding of the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.